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PLANAR IMAGE PARTICLE ANALYZER FOR WHOLE FIELD SPRAY APPLICATIONS

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The purpose of this work is to develop a whole field measurement technique that is capable of simultaneously sizing multiple transparent droplets on a plane from scattered light features that are independent of laser beam intensity and obscuration. Light scattered by reflection and refraction from droplets immersed in a laser sheet is recorded holographically to yield the smallest possible probe volume and correspondingly largest number density. Last year we reported droplet size results obtained with conventional optical holography and some preliminary results of different objects obtained with digital holography. This year we report the first droplet size results obtained with digital holography.

DESIGN AND DEVELOPMENT OF A DIGITAL HOLOGRAPHIC PIPA-SYSTEM

The recording medium in the case of digital holography is a high resolution CCD-sensor. Holograms collected on this sensor are subsequently reconstructed mathematically yielding complete 3-D information of the object. Figure 1 shows a schematic of the system. The laser was a pulsed ruby laser. The remaining components are lenses (Li), mirrors (Mi), and beamsplitters (BSi)

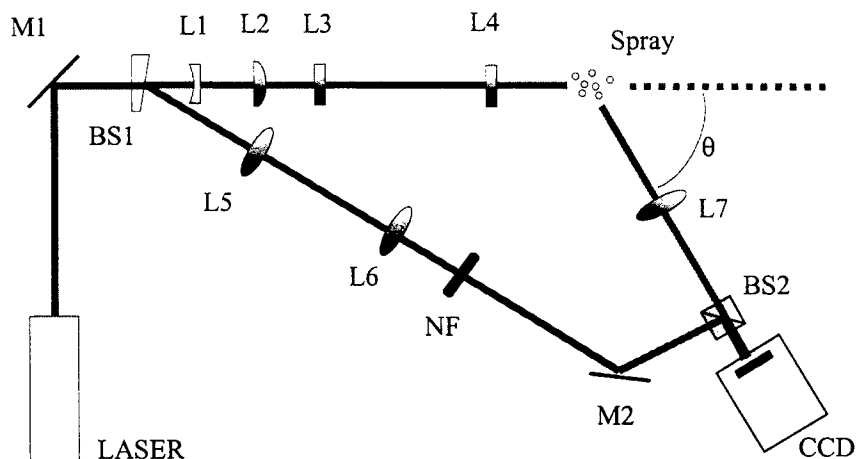


Fig. 1 Schematic of digital holographic PIPA system

A manual sprayer filled with water generated the spray. The droplets were aimed manually into the light sheet. The distance between the CCD-sensor and the image of the laser sheet was about

5 cm. In this configuration a defocused image was recorded and the focused image was subsequently calculated using the digital holography algorithm.

EVALUATION OF RESULTS

Figure 2 shows a typical hologram recorded with the system described above.

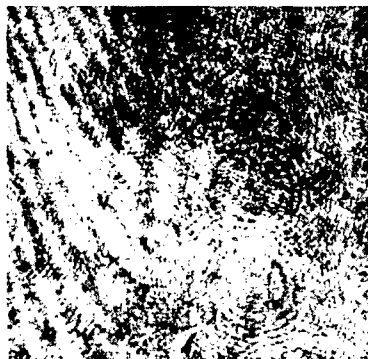


Fig.2 Digital hologram of water droplets

Although the contrast is poor, spherical interference fringes generated by the droplets can be observed. The holograms serve as input for the digital reconstruction procedure. In Fig.3 the reconstructed intensity is shown for different distances.

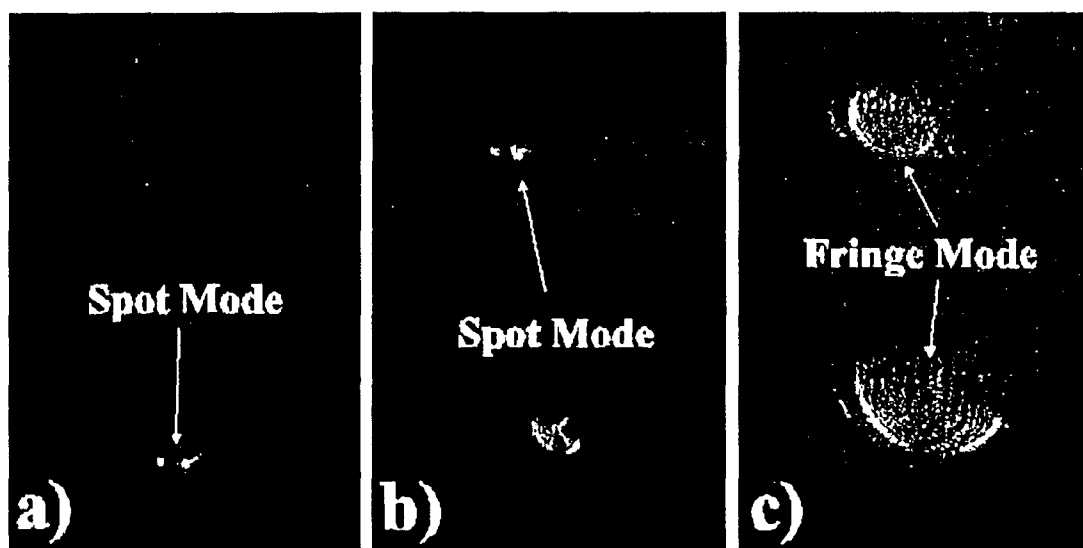


Fig.3 Reconstruction of droplets at a reconstruction distance of a) 4.6 cm, b) 5.1 cm and c) 5.8 cm

The results show that the spots of the refracted and reflected spherical waves can be reconstructed and evaluated. The diameter of the droplets were calculated from the spot separation in the reconstruction. In the case of the upper droplet the separation was determined to be 109 μm (Fig 3a) and in the case of the lower droplet 143 μm (Fig. 3b).

The spot separation can easily be determined from the numerical reconstruction. The fringes in Fig. 3c) have a poor contrast due to a high noise level and different intensities of the spots. Furthermore the intensity patterns in Fig. 3 c) are not spherical. This is because the imaging system and/or the CCD did not collect part of the reflected/refracted light. This problem can be

mitigated by optimizing the imaging system and by reducing the distance between image and CCD-target.

The experiments show that the undesired virtual image appears as background noise. It reduces the image quality but it does not overlap with the real image, which would make further evaluation impossible. The noise can be reduced using a filtering technique that also can be used to separate the information from different droplets. This filter is described in detail in the next section.

APPLICATION OF NUMERICAL FILTER

In order to avoid the overlapping of reflected/refracted wavefronts from different, adjacent droplets a filter can be applied in digital holography. This filter can also be used to reduce the noise in the reconstructed image. The principle of this filtering technique is shown in Fig.4.

In the presence of noise the fringes reconstructed with digital holography have a poor contrast. To apply the numerical filter the complex wavefront corresponding to each droplet is first reconstructed in the 'spot-mode'-plane where the wavefront of interest has its minimal extension and can be separated from noise and other spots. This is achieved by multiplying the complex image with a window function that takes a value of 1 in the region of interest and 0 elsewhere. Subsequently to applying the filter the numerical reconstruction is used to reconstruct the wavefront at a convenient 'fringe-mode'-plane. The result of the filtering is shown in Fig. 4b). In comparison with Fig. 4a) the fringes are less noisy and the second droplet does not exist.

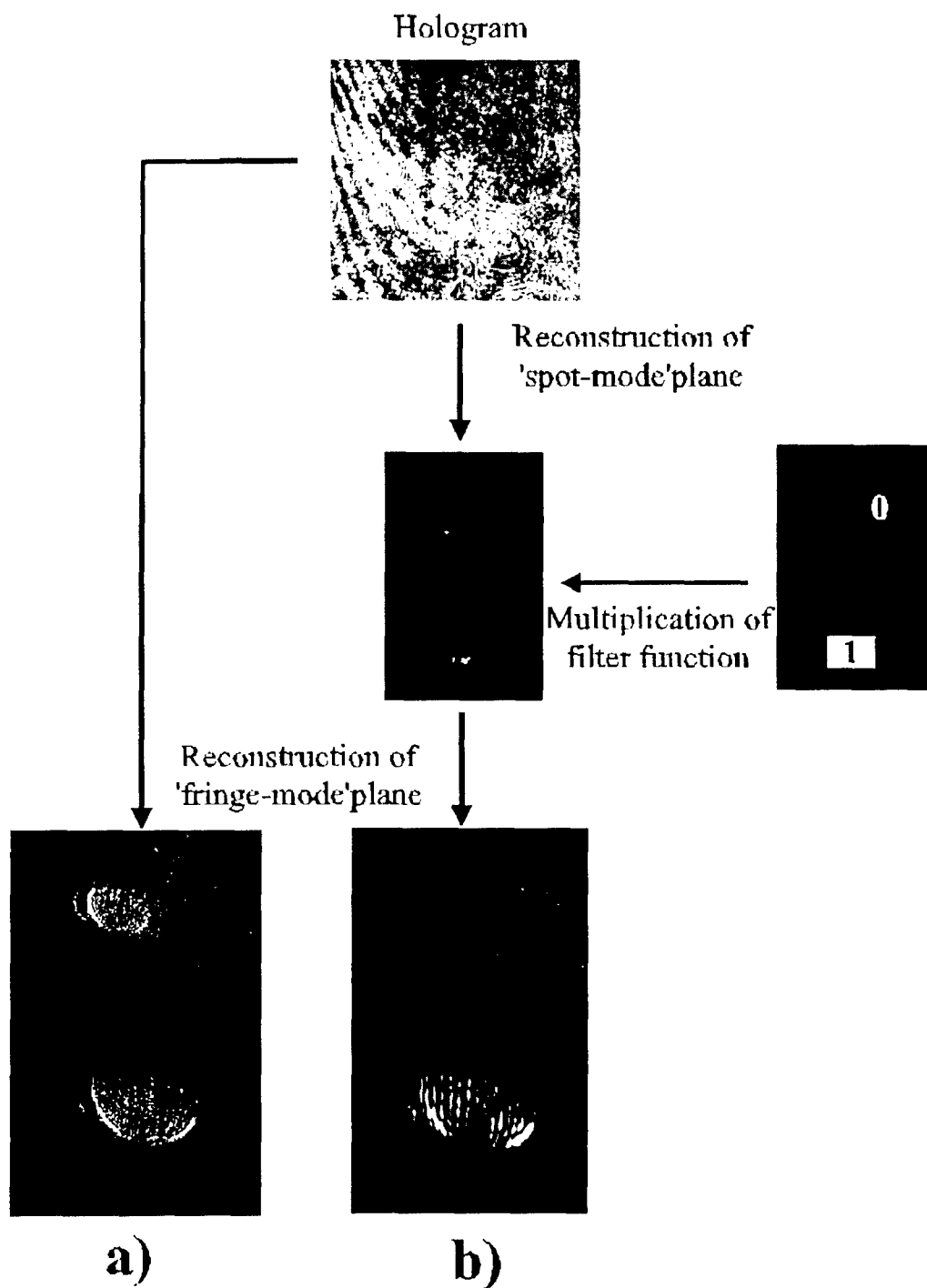


Fig.4 Reconstruction without (a) and with application of filter (b)

CONCLUSIONS

We have demonstrated the ability to record and numerically reconstruct wavefronts corresponding to single droplets both in the two-spot and the fringe mode regimes. A numerical filter applied to images reconstructed in the two-spot regime significantly improved the quality of the fringes.